Quantifying Benefits of Large-Scale Coastal Restoration

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Overview

- Acknowledgements
  - EBA Research Program
  - New Orleans District
  - FWS: Ronny Paille, Tamieka Armstrong
  - NRCS: Ron Boustany
  - LACPR Habitat Evaluation Team

- Overview
  - Louisiana Coastal Protection and Restoration (LACPR)
  - Metric Selection
  - Flow Diversion Model
  - Applications
  - Future Thoughts and Closing Remarks

Louisiana Coastal Protection and Restoration (LACPR)

- Wetland Loss: 77 km^2/yr since 1978
- Hurricanes Katrina and Rita
- Congressional Mandate to "conduct a comprehensive hurricane protection analysis and design…to develop and present a full range of flood control, coastal restoration, and hurricane protection measures"
- Make recommendations to Congress

Habitat Evaluation Team (HET): Overall Aim/Approach

- Build upon previous efforts and conventional knowledge
- Identify plans that sustain the integrity of the estuarine environments
- Decisions based upon HET consensus, informed where possible by analysis and quantification
- Explicitly address uncertainty and identify means to manage risk

LACPR: Planning Units

PU1: Pontchartrain Basin

PU2: Barataria Basin

PU3a: Terrebonne Basin

PU3b: Atchafalya Basin

PU4: Chenier Plain

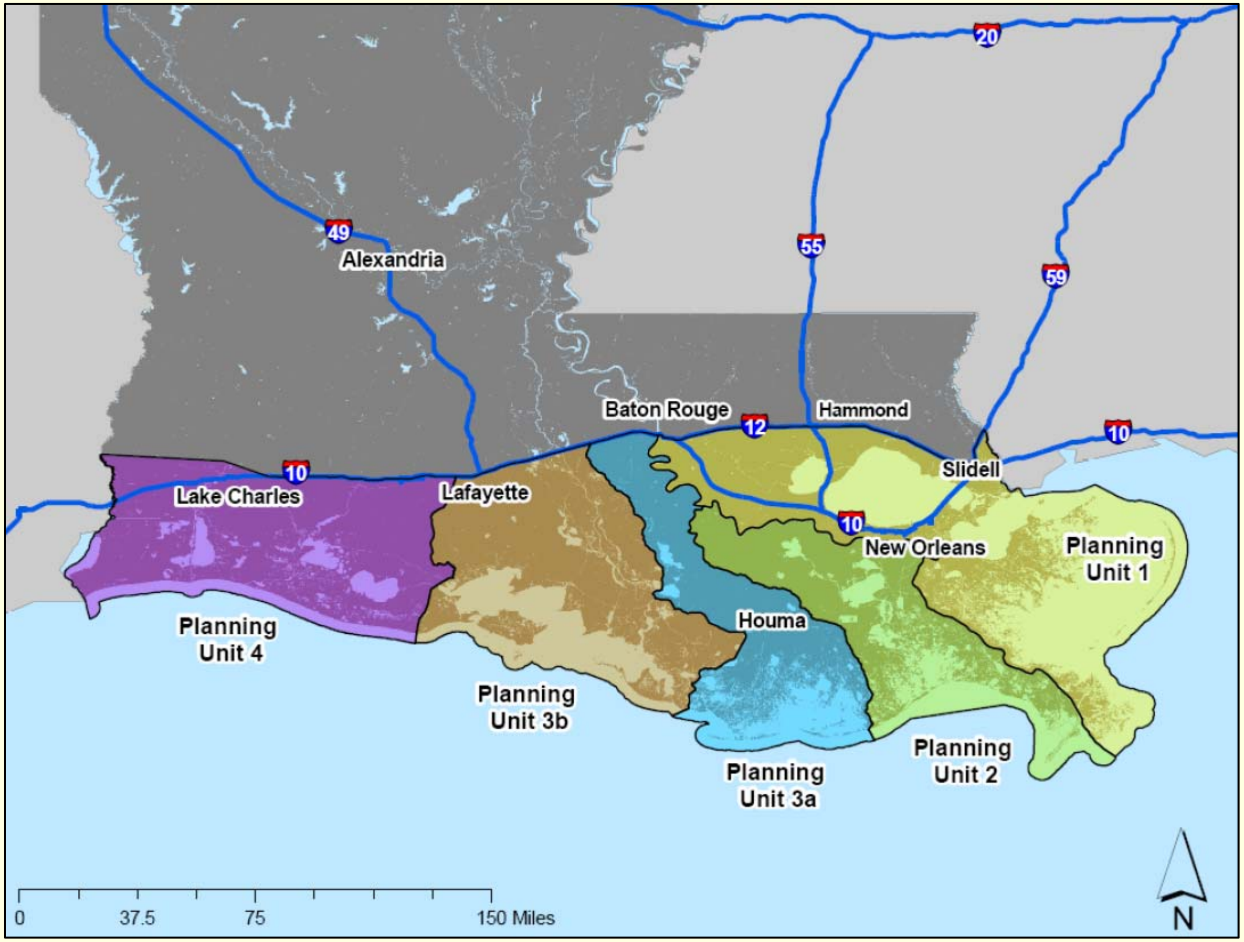


Figure from LACPR Draft Report

Coastal Restoration: Management Measures

- Primary focus on measures that contribute to estuarine maintenance at a basin scale
- Landscape Features
  - Marsh creation
  - Ridge/Chenier restoration
  - Barrier island restoration
  - Shoreline stabilization
- Freshwater Diversions

Prioritizations

PU	Creation & Protection Features	Structural Import.	Function Lifespan	Synergy w Diversion
3a	3DR-east red polys (9,10,11,16,19,21,22,28)	3	3	1
3a	Terr Bay N. Rim (JeanCh. To B.Terr)	3	3	1
3a	South Caillou Lake Landbridge MC (polys 20-22)	3	3	0.5
3a	Timbalier Islands Restoration	3	3	0
3a	Isle Derniers Restoration	3	2	0
3a	DuLarge-Grand Caillou Landbridge MC	2	3	1
3a	Small Bayou la Pointe Ridge	2	3	1
3a	3DR-east orange polys (S1,13,17,20,29,30)	2	3	0.5
3a	Bayou DuLarge Ridge	2	2	1
3a	3DR-west green polys (1,2,3,4,8)	2	2	0.5
3a	South Caillou Lake Landbridge MC (polys 19,23,24)	2	2	0
3a	Bayou Pointe au Chene Ridge	2	2	0
3a	3DR -east blue polys (8)	1	3	1
3a	3DR-west blue polys (5,6,7)	1	3	0
3a	Terr Bay N. Rim (Pt.Chen to JeanCh.)	1	2	1
3a	Margaret's Bayou Ridge	1	2	1
3a	Terr Bay N. Rim (Latch to Pt.Chene)	1	1	1
3a	Terr Bay N. Rim (B.Terr to west end)	1	1	0
3a	Bayou Terrebonne Ridge	0	3	0
3a	3DR-east green N polys (2,7,12,14)	0	2	1
3a	3DR-east green S polys (N1,3,4,5,6,15,16,18,23-27)	0	2	0

Identifying Metrics

- Conceptual Models
- Risk-Informed Decision Framework (RIDF)
  - Multi-Criteria Approach
- Coastal Restoration Metrics
  - Storm Damage Reduction
  - Estuarine Spatial Integrity
  - Wetland Acreage

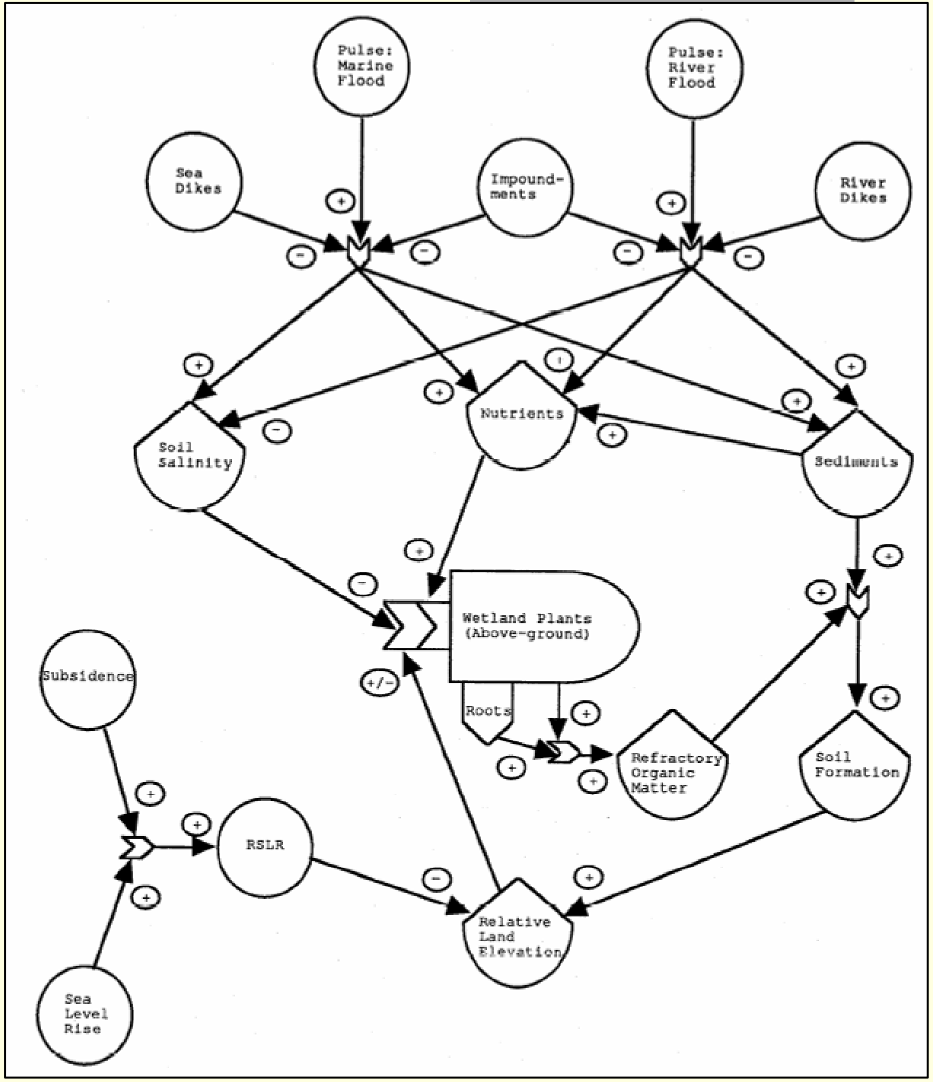
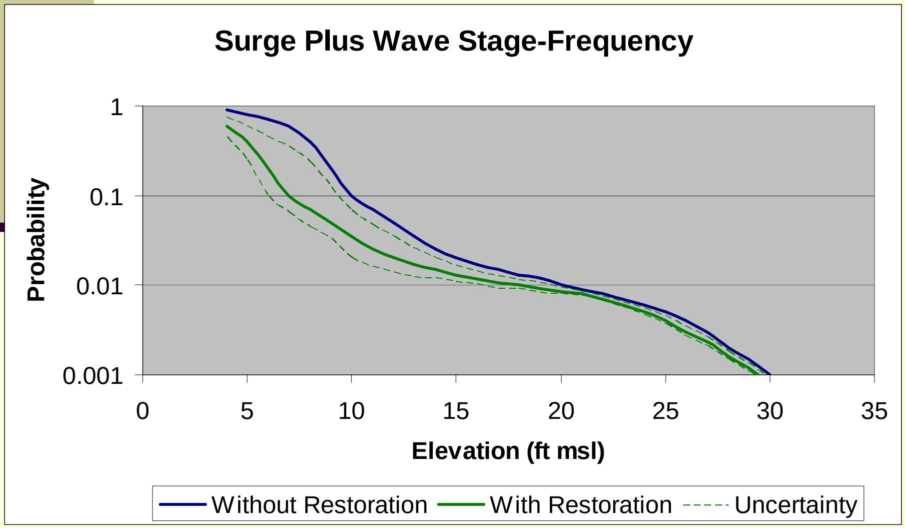
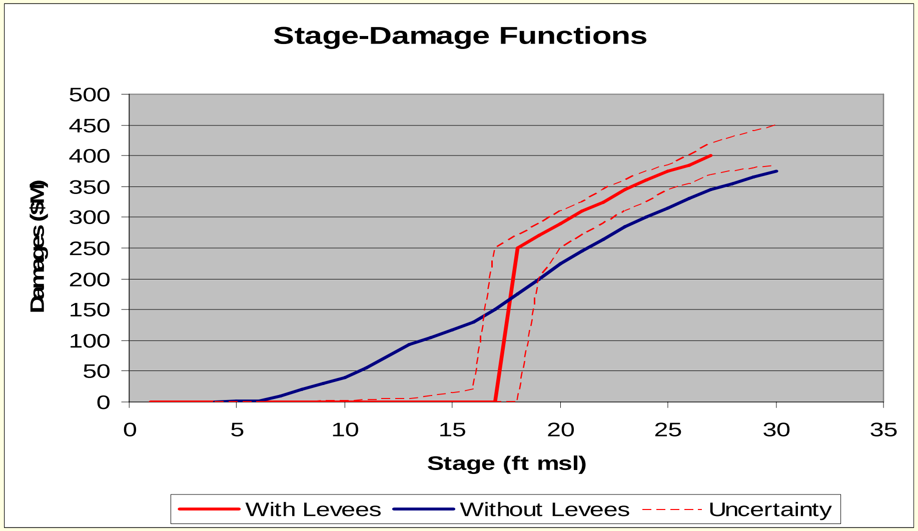


Figure from Day et al. (1995)

Storm Damage Reduction

- Benefits quantified as reduction in Expected Annual Damages ($)
- Analysis using ADCIRC-STWAVE models for with- and without-coastal features
- Uncertainty – resistance, bathymetry, economics
- Stage-frequency curve integrated with stage-damage curve for benefits

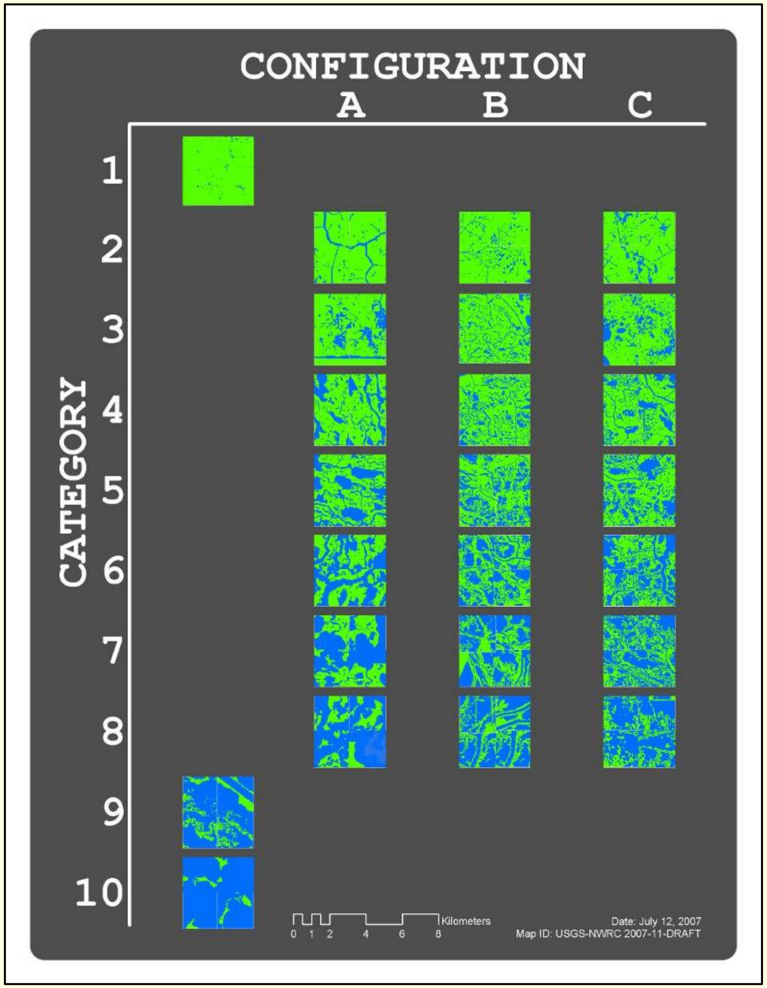




Spatial Integrity

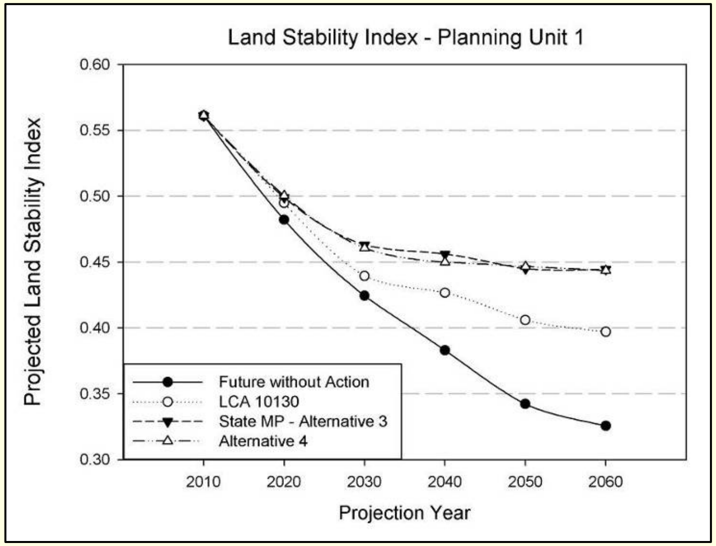
- Conceptual approach defines the landscapes by:
  - Structure: the spatial relationship among distinct wetland patches or their elements
  - Function: the flow of mineral nutrients, water, energy, or species among component patches or between landscapes
  - Change: the temporal alterations in the structure and function of landscapes or their components
- Premise: structure, function and change of patches affect fundamental ecosystem processes, which determine the trajectories of ecological condition.

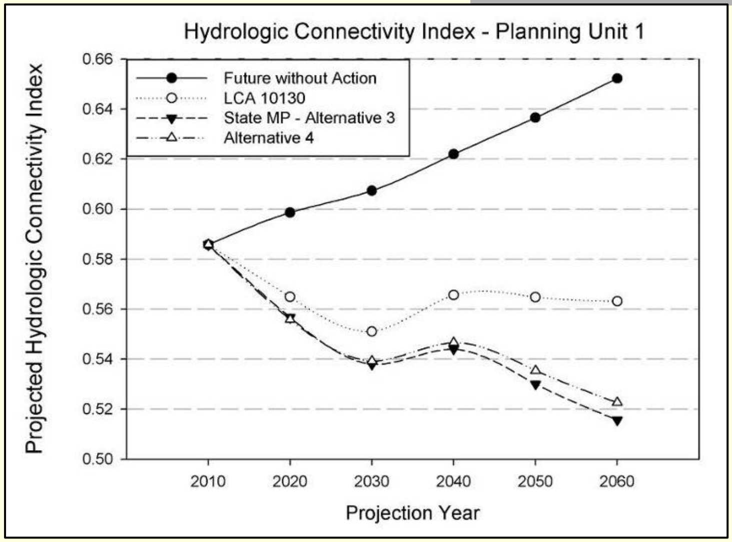
Spatial Integrity Classification

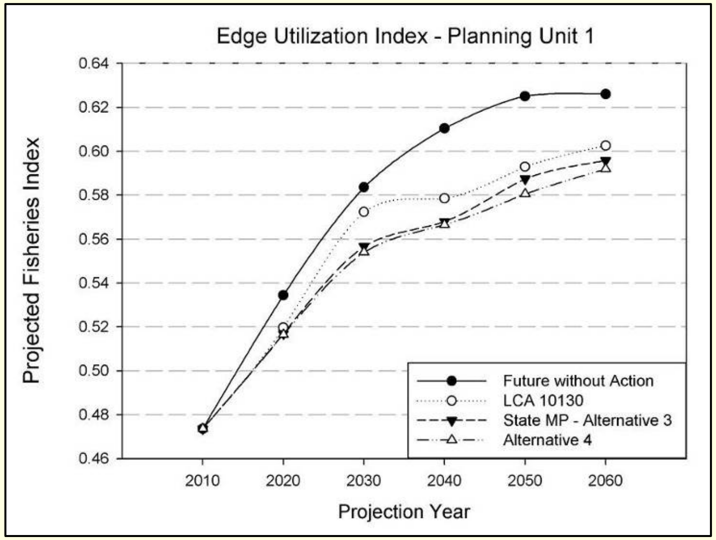


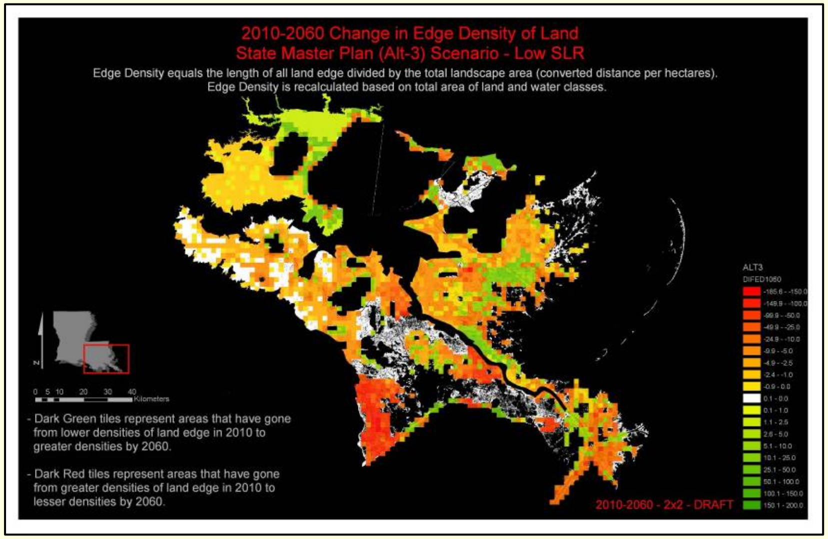
Hydro Connectivity		Fisheries		Land Stability	
1	0.0417	10	0.0417	10	0.0417
2B	0.0833	1	0.0833	9	0.0833
3B	0.1250	2A	0.1250	6B	0.1250
2C	0.1667	8A	0.1667	5B	0.1667
4B	0.2083	9	0.2083	5C	0.2083
2A	0.2500	3A	0.2500	4C	0.2500
3C	0.2917	7A	0.2917	2C	0.2917
4C	0.3333	2B	0.3333	7C	0.3333
5B	0.3750	6A	0.3750	8C	0.3750
3A	0.4167	5A	0.4167	4B	0.4167
4A	0.4583	4A	0.4583	3C	0.4583
6B	0.5000	8B	0.5000	3B	0.5000
5C	0.5417	2C	0.5417	6C	0.5417
7B	0.5833	7B	0.5833	2B	0.5833
5A	0.6250	8C	0.6250	8B	0.6250
6C	0.6667	3C	0.6667	7B	0.6667
7C	0.7083	3B	0.7083	6A	0.7083
6A	0.7500	6B	0.7500	7A	0.7500
8B	0.7917	7C	0.7917	5A	0.7917
7A	0.8333	4C	0.8333	8A	0.8333
8C	0.8750	6C	0.8750	4A	0.8750
8A	0.9167	4B	0.9167	3A	0.9167
9	0.9583	5C	0.9583	2A	0.9583
10	1.0000	5B	1.0000	1	1.0000

Spatial Integrity Example (cont)







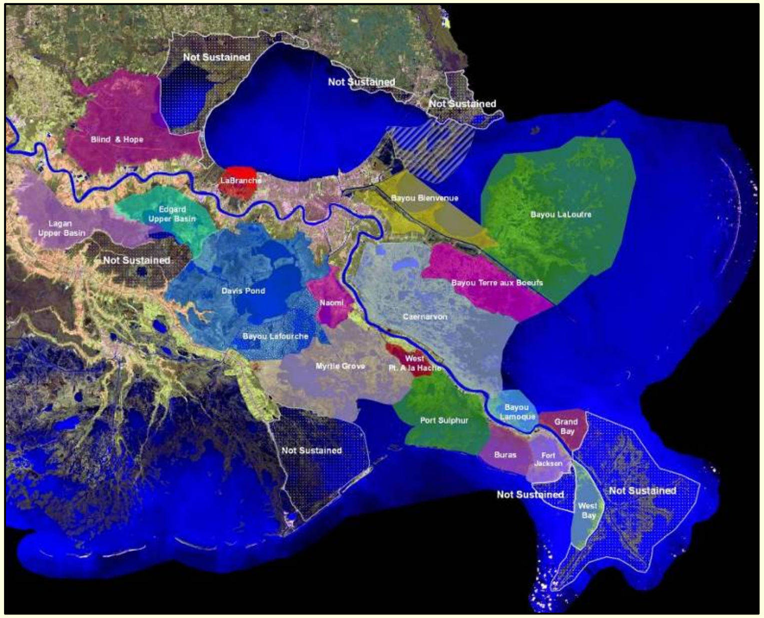


Wetland Acreage

- Existing
- Created with Dredged Material
- Created by Diversion
- Effective Land Loss Rates

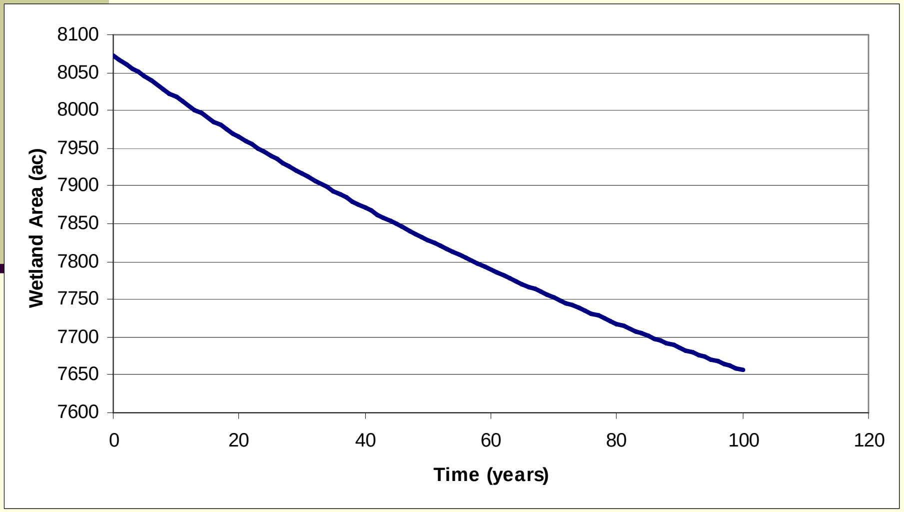
Wetland Acreage: Freshwater Diversions

- Sediment and nutrient inputs offset losses due to consolidation, subsidence, SLR, erosion, etc.
- Limited replication of historic deltaic processes



Model Selection

- Selection Criteria:
  - Inorganic (sediment) and organic (nutrient-growth) components
  - Rapid application
  - Readily available data
  - Uncertainty Analysis
- CWPPRA Diversion Model



	A	B
1	**Site**	**Sample**
2		
3	Flow Rate (cfs)	650
4	Number of days	365
5	Acre-ft of water	474500
6	Volume of water (L)	5.85E+11
7		
8	**Nutrients**	
9	Productivity Rate (gdw m^{-2} y^{-1})	2653
10	% Retention	50%
11	% N/P	1.5%
12	g m^{-2} NP	39.795
13	kg/acres NP (Required)	161.113
14	NP Concentration (net)	1.5
15	Total NP (kg) (Available)	878028.5
16	Nutrient Potential Acres	2725
17	Land Loss Rate	-0.69%
18	**Nutrient Acres**	**18.8**
19		
20	**Sediments**	
21	TSS Concentration (mg/l)	70
22	Bulk Density (g cm^{-3})	0.16
23	% Retention	15%
24	Average Depth (ft)	1.0
25	TSS (g) (Available)	4.10E+10
26	Sediment Potential Acres (acre-ft y^{-1})	207.6
27	**Sediment Acres**	**31.1**
28		
29	**TY1 Acres (Gross Annual Acres)**	**49.9**
30	TY50 Acres	999
31	TY100 Acres	4994
32		
33	**Area (acres)**	8073
34	Annual Land Loss Rate	-0.69%
35	Annual Land Loss	-55.7037
36	**Adjusted Annual Net Acres**	**-5.8**
37	**Adjusted Land Change Rate**	**-0.07%**
38		
39	**Area Sustained (zero loss rate)**	**7238**
40		

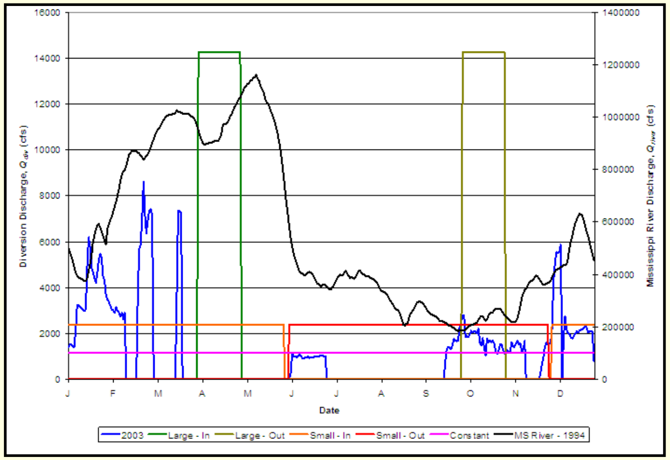
	A	B
42	**TY**	**Area**
43	0	8073
44	1	8067
45	2	8062
46	3	8056
47	4	8050
48	5	8045
49	6	8039
50	7	8034
51	8	8028
52	9	8023
53	10	8017
54	11	8012
55	12	8006
56	13	8001
57	14	7996
58	15	7991
59	16	7985
60	17	7980
61	18	7975
62	19	7970
63	20	7965
64	21	7960
65	22	7955
66	23	7950
67	24	7945
68	25	7940
69	26	7935
70	27	7931
71	28	7926
72	29	7921
73	30	7916
74	31	7912
75	32	7907
76	33	7902
77	34	7898
78	35	7893
79	36	7889
80	37	7884
81	38	7880
82	39	7875
83	40	7871

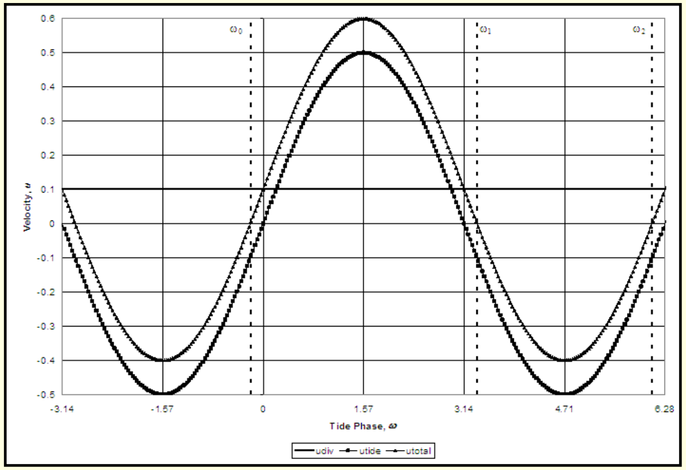
Why modify the CWPPRA model?

- Other tools were:
  - Overly complex for LACPR timeline
  - Unable to rapidly examine operational and structural differences
- Key Model Assumptions
  - Nutrients reduce land loss rate, but do NOT contribute to marsh accretion
  - Only NET nutrient increase is considered
  - Spatially uniform, simplified marsh geometry
  - Temporal resolution
    - Only represented intra-annually, not in a continuous format
    - Organic accumulation is not seasonally driven
    - No habitat switching with time
  - No vegetative component to settling/roughness
  - Additional loss mechanisms are not addressed – canals, rainfall, tidal flows, waves, or hurricanes
  - Sheetflow assumed for all diversion flow rates
  - Uniform distribution of sedimentation.

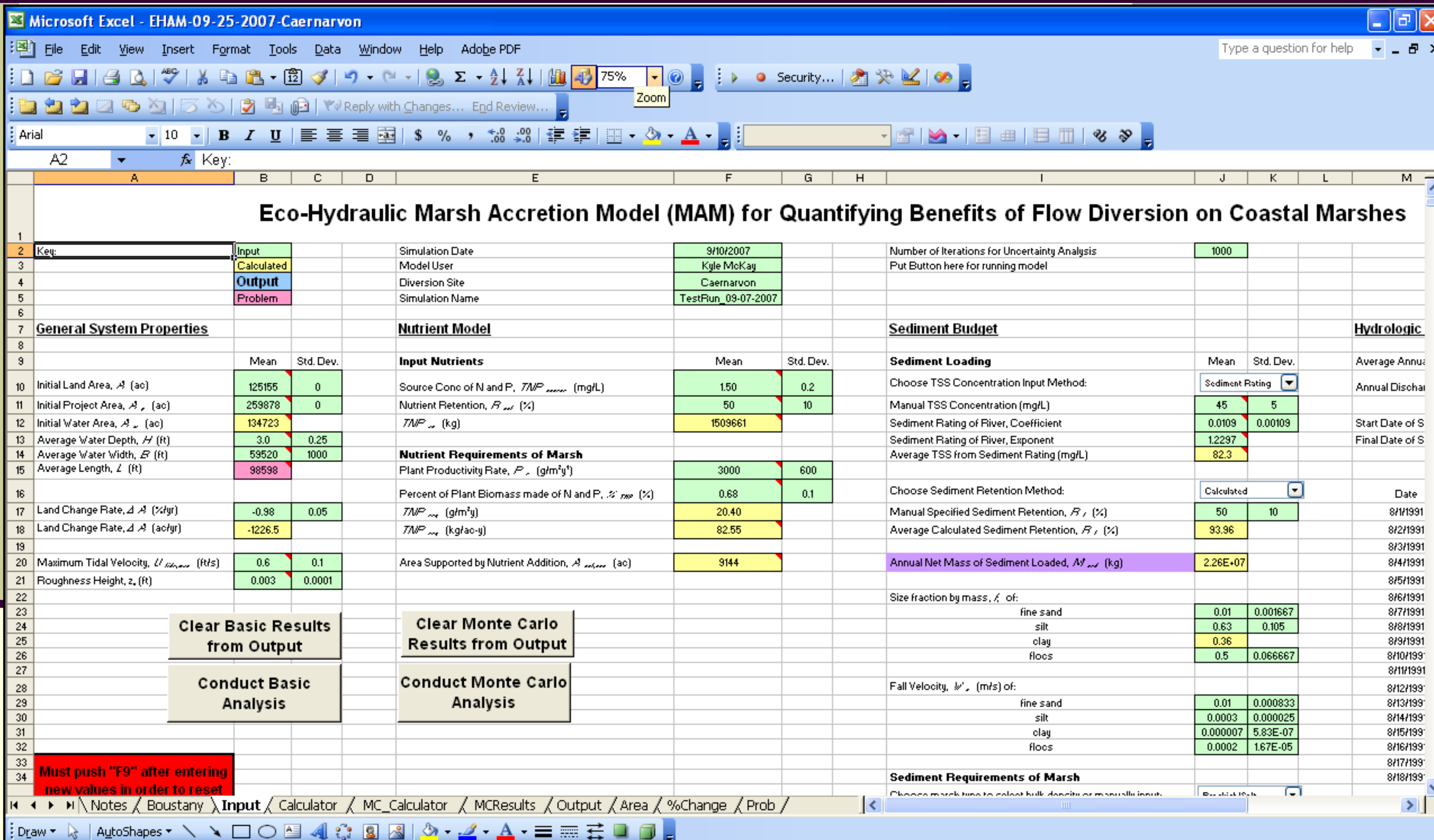
Changes to CWPRA Model

- Discharge specification options
  - Steady or varying
  - Flow duration option
  - Coupling to river flows
- Sediment loading options
  - Concentration or load
  - May be specified as a rating
- Sediment disposition computation
  - Rouse settling velocity
  - Particle size dependent
  - Accounts for flocculants
  - Includes tidal velocity
- Bulk density
- Stochastic analyses

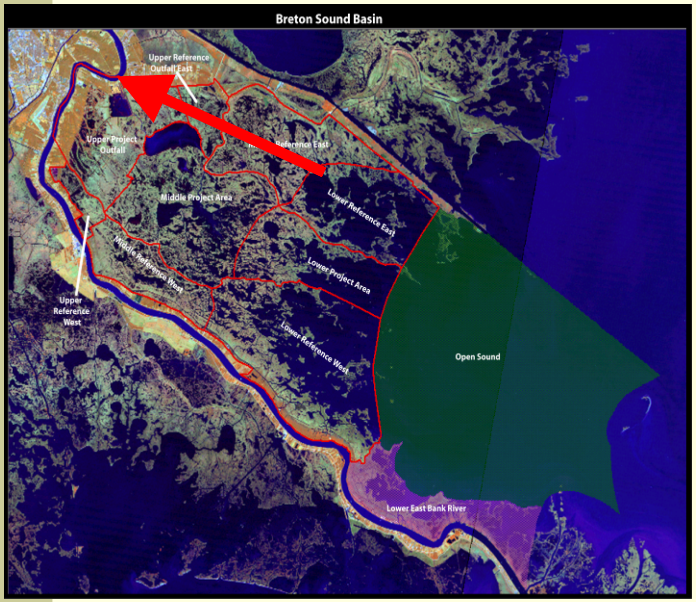


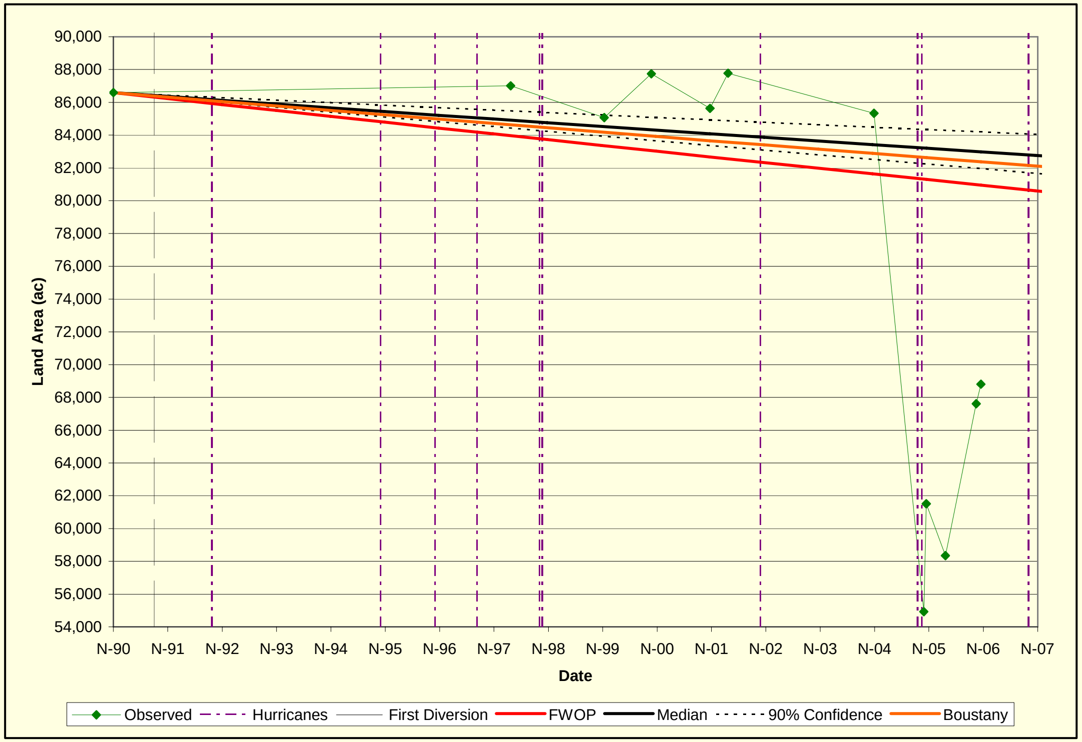


Desktop Model



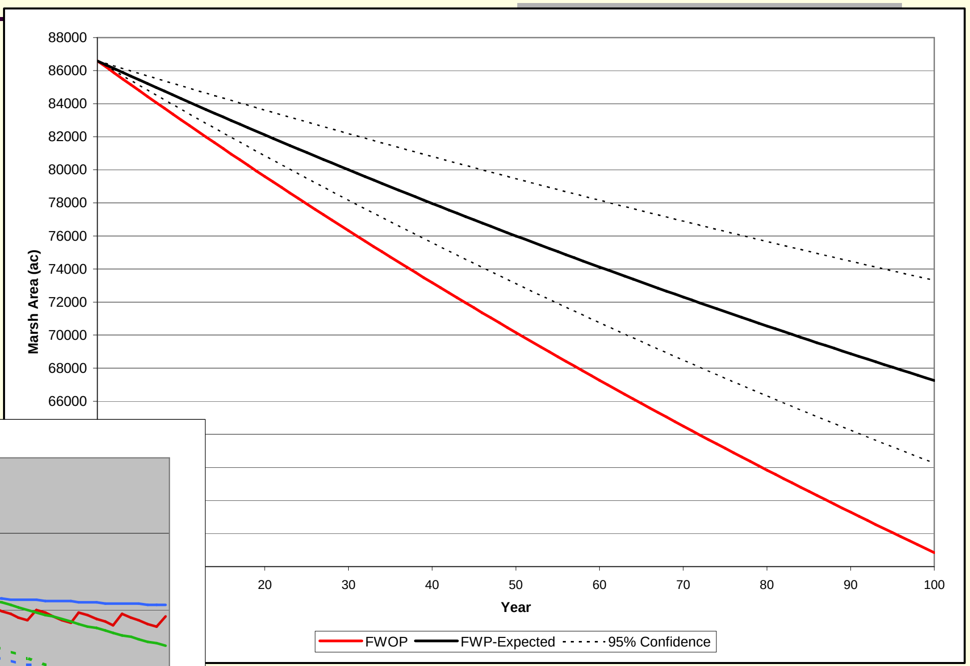
Model Testing: Caernarvon

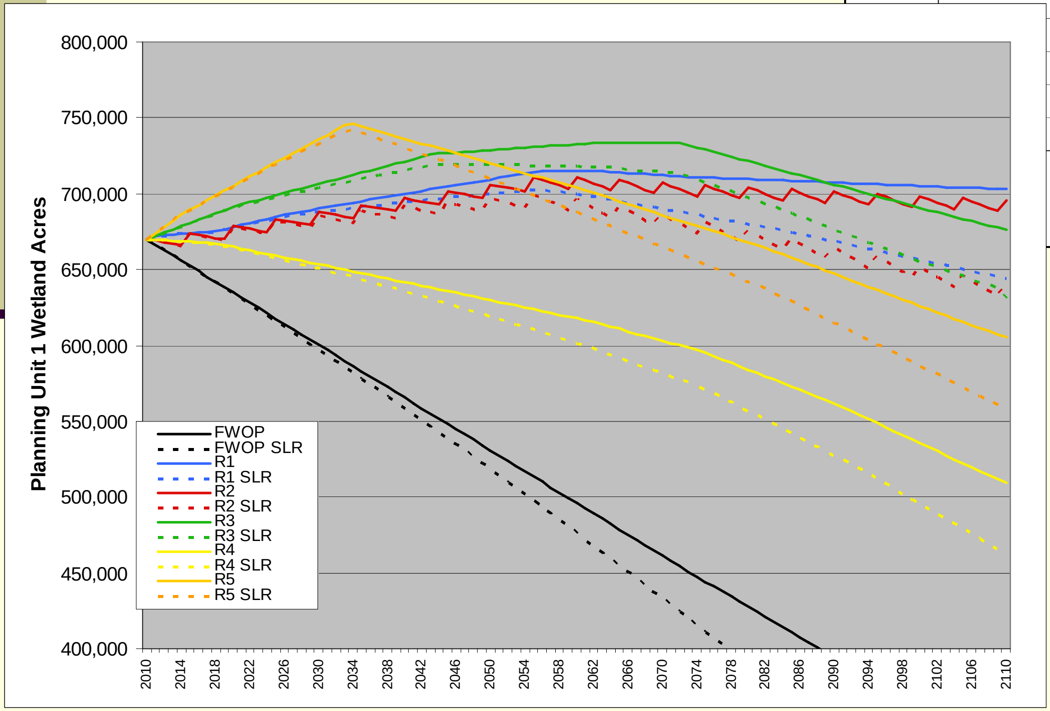




Uncertainty Analysis

- Parameter: Monte Carlo Simulation
- Scenario: Sea Level Rise

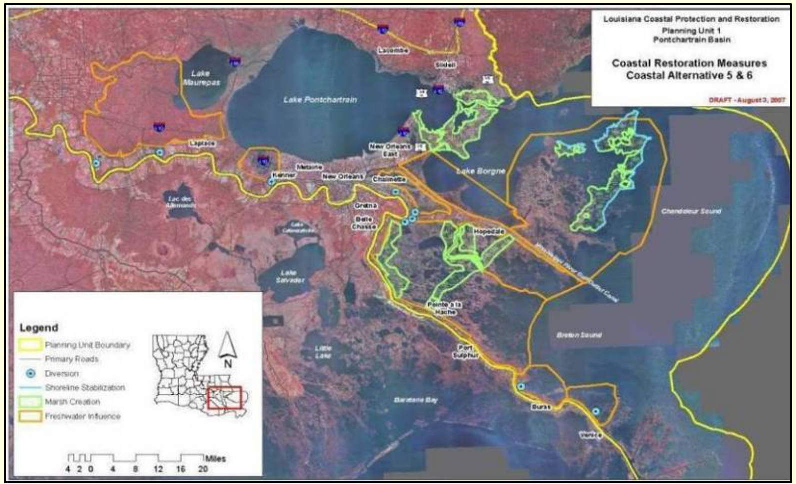




Limiting Factors

- Total diversion discharge < 525,000 cfs (confirmation and refinement needed)
- Annual sediment availability ~ 30M c.y. (figure disputed; alternate sources?)
- Mechanical marsh creation production rate roughly 900 ac/yr/dredge (total number of dredges constrained)
- Dredging costs not considered a constraint, but are a key consideration

Restoration Alternatives



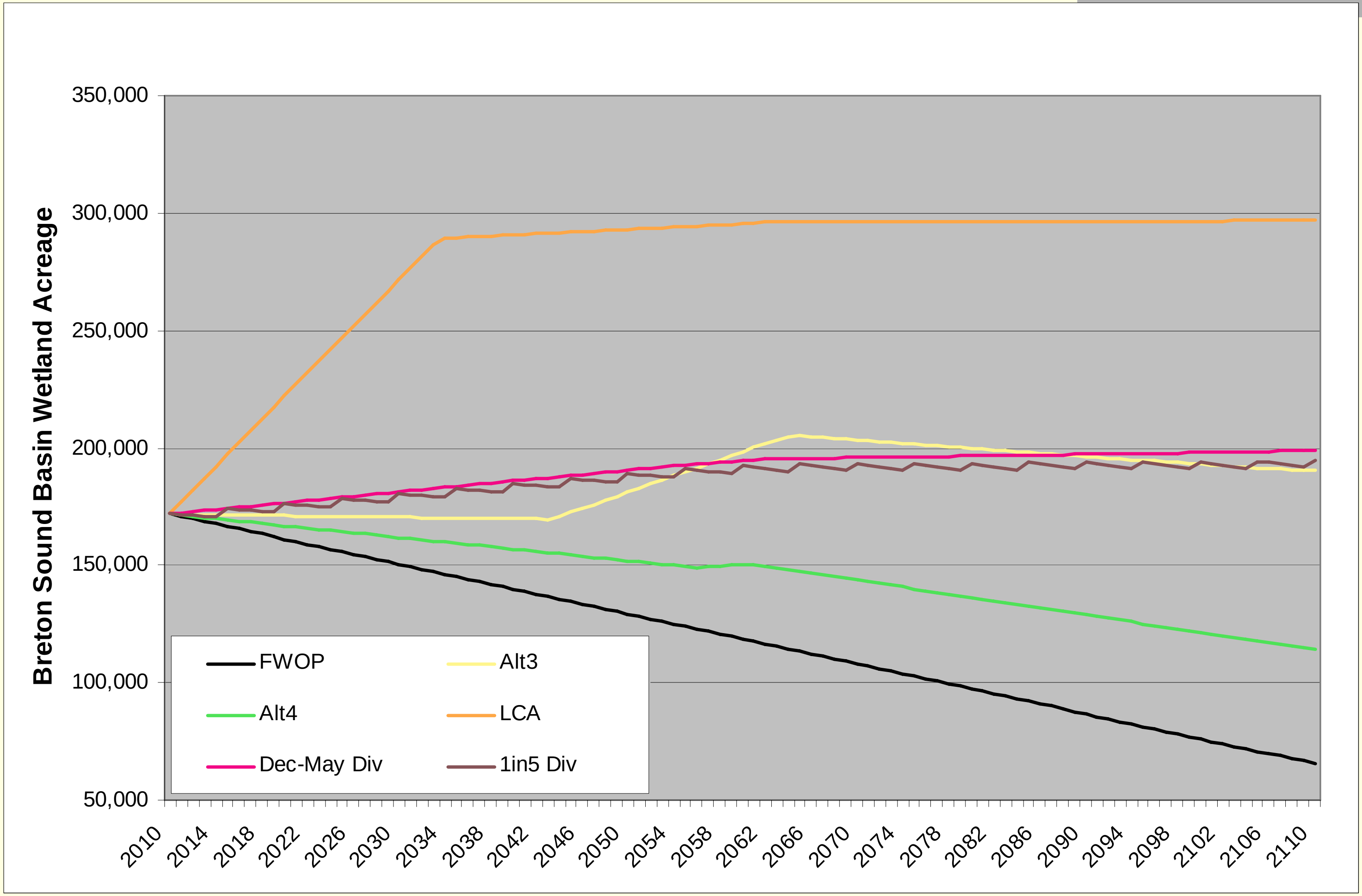
1. Do Nothing (FWOP)
2. LCA 10130 (PBMO)
3. State Master Plan
4. EIS Alternative 4
5. MC features + medium diversion
6. MC features + pulsed diversion

Figure from LACPR Draft Report

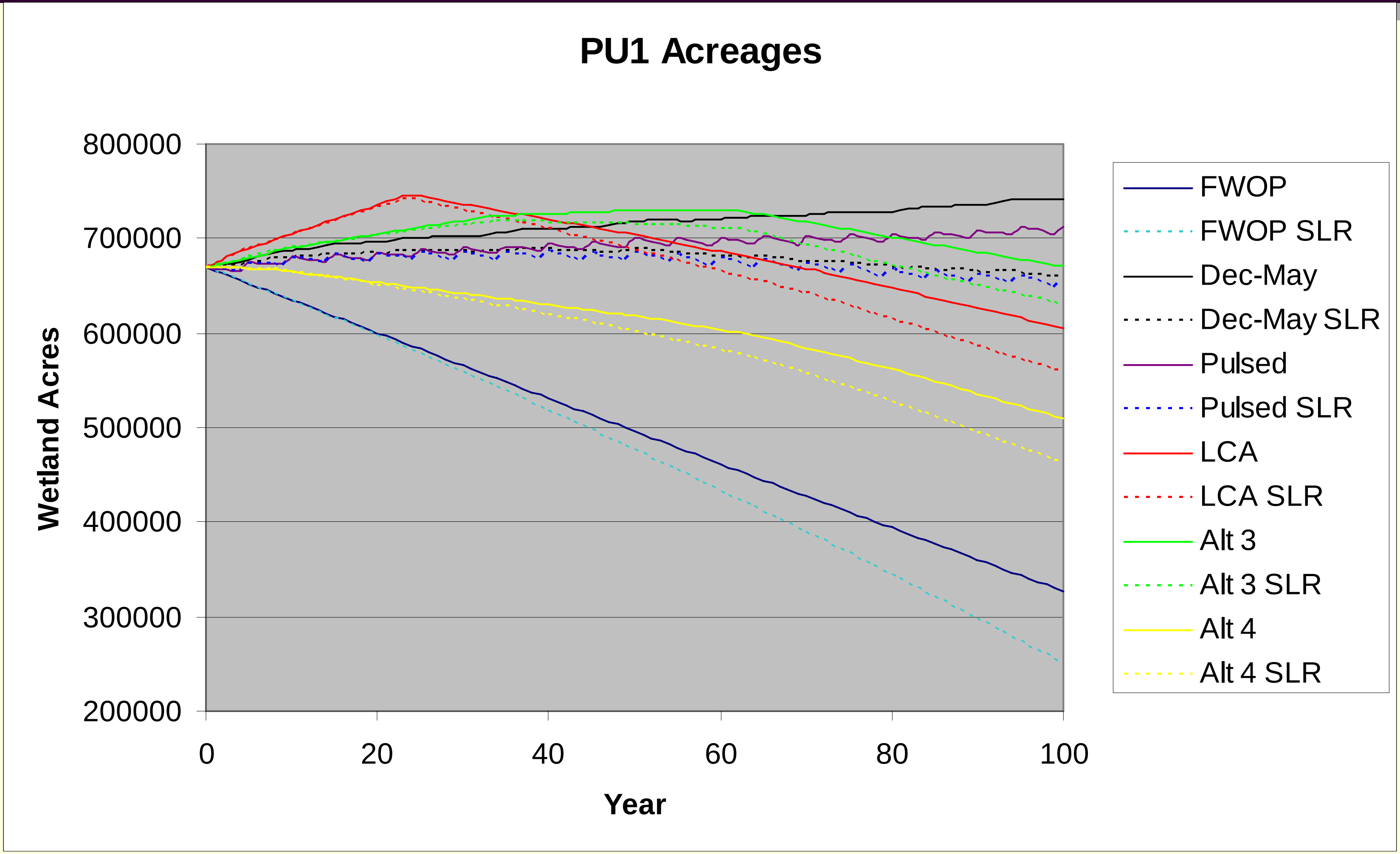
PU1-Pontchartrain; Alternative 5

- Blind River Diversion - flows for sustaining entire south Maurepas swamp split between Blind River and Hope Canal
- Hope Canal Diversion - flows for sustaining entire south Maurepas swamp split between Blind River and Hope Canal
- LaBranche Diversion – diversion directly into LaBranche wetlands to sustain those wetlands
- Bayou Bienvenu Diversion – to reduce East New Orleans landbridge loss rates by 50%
- East New Orleans land bridge Marsh Creation – 7,996 acres @ 900 acres/year
- Bayou LaLoutre Diversion – (In lieu of Violet) sized to sustain the Biloxi Marshes
- Biloxi Marshes Shore Protection – 254,500 linear feet of protection around outer perimeter
- Biloxi Marshes Marsh Creation – 33,553 acres of marsh creation with armored containment dikes where not already provided by Biloxi Marshes Shore Protection measure
- Bayou Terre aux Boeufs Diversion - flows to sustain marshes between MRGO and Bayou Terre aux Boeufs
- Bayou Terre aux Boeufs Marsh Creation – 2,591 acres in upper basin
- Breton Sound Strategic Land Bridge – a band of marsh from MRGO to Miss. River (14,579 acres) plus marsh creation along either side of Bayou LaLoutre
- Caernarvon Diversion – sized to sustain all marshes between Bayou Terre aux Boeufs and the Miss. River
- Caernarvon Area Marsh Creation – Marsh creation along protection levee from Big Mar south to Pheonix (4,936 acres)
- Bayou Lamoque Diversion – to sustain receiving area marshes
- Grand Bay Diversion – sized to sustain receiving area marshes

LACPR: Polygon Scale

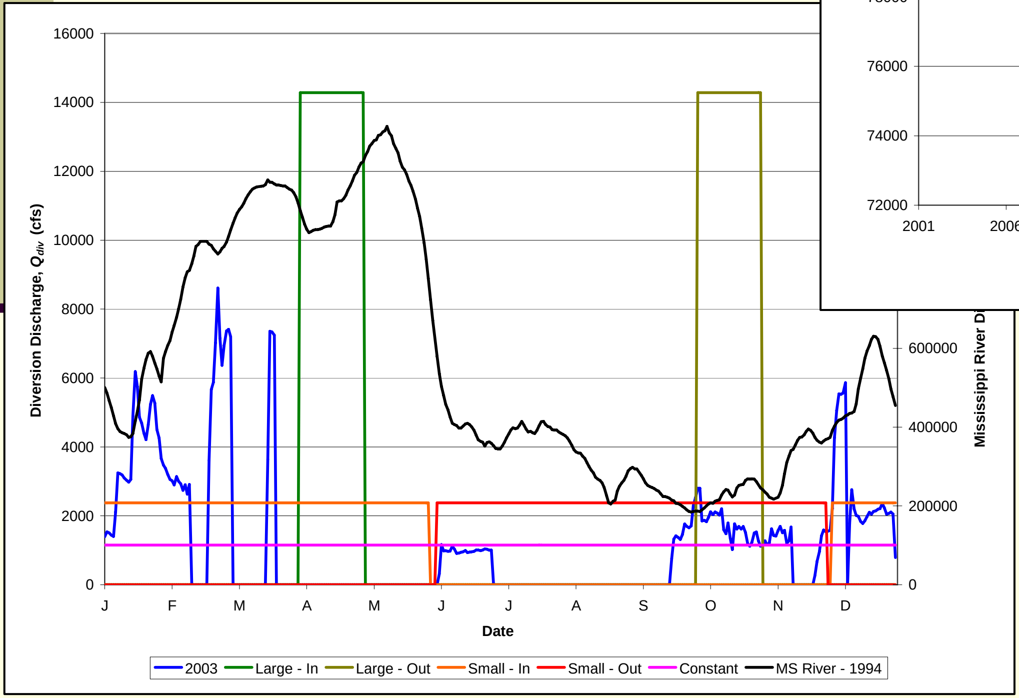


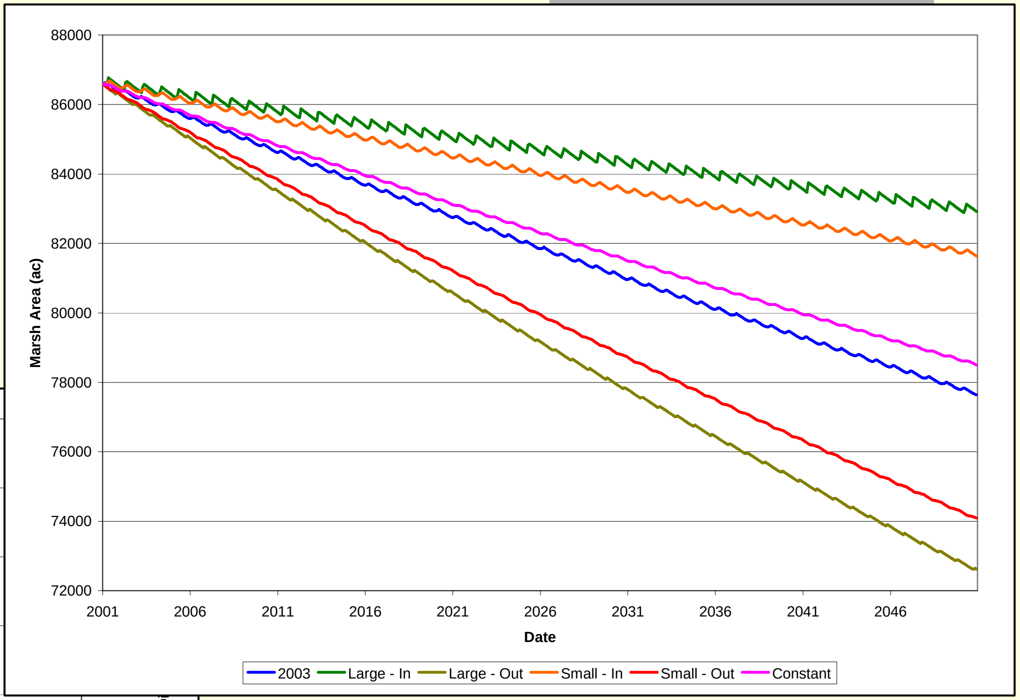
LACPR: Basin Scale



Operational Alternatives

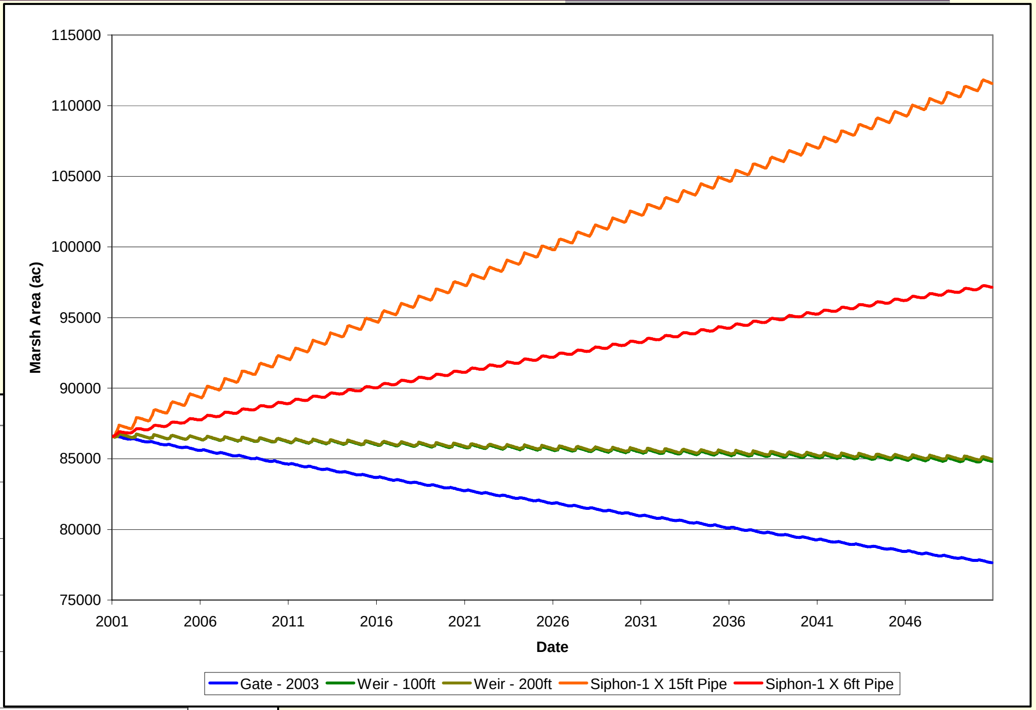
- Equal Volume Alternatives:
  - Observed
  - Steady flow
  - Pulses – large and small
  - Timing – in and out of phase with river

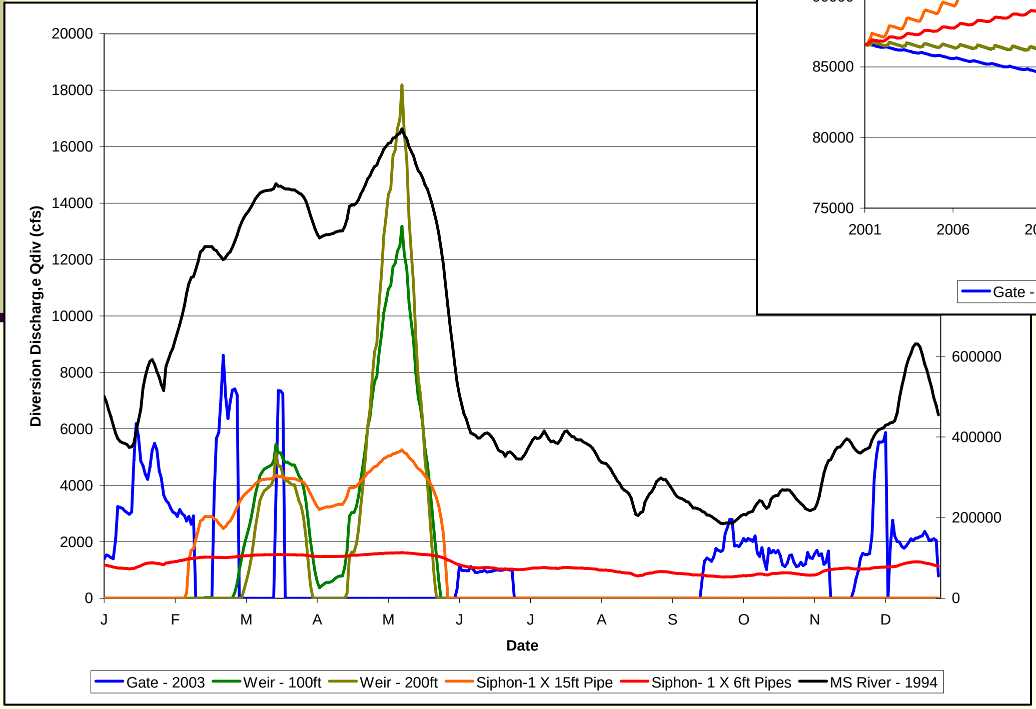




Structural Alternatives

- Equal Volume Alternatives:
  - Gate
  - Weirs – large and small
  - Siphon – large and small





Future Enhancement

- Donaldsonville to the Gulf
  - Spatially distributed delta growth
  - Continuous simulation
  - Land loss rate thresholds
- Future Improvements:
  - Update nutrient module to resolution of sediment module: seasonality, eutrophication, multiple limiting factors
  - Spatially distributed modeling
  - Improved hydrodynamic assessments – canals, erosion, shallow distributed flows

Conclusions

- LACPR required rapid development of alternatives and solutions
  - Multi-Criteria Approach
  - Use of conceptual models for metric identification
  - Storm Damage Reduction, Spatial Integrity, Wetland Acreage
- Flow diversion = common restoration measure
- Screening of location, magnitude, structure type, and operation was needed
- LACPR Flow Diversion Model
  - Adapted from existing tool
  - Updated based on known processes and time constraints
  - Parameter and scenario uncertainty analyses conducted

Questions?

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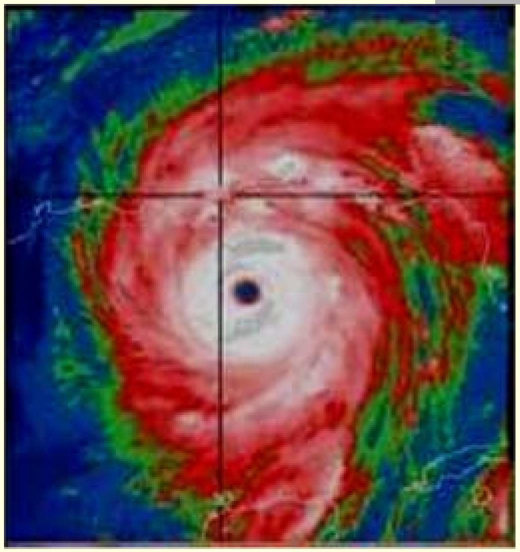

LACPR Information:
http://lacpr.usace.army.mil/

Forthcoming Publications:

McKay, Fischenich, and Smith. Quantifying Benefits of Flow Diversion to Coastal Marshes I: Theory. In preparation for *Ecological Engineering*.

McKay, Fischenich, and Paille. Quantifying Benefits of Flow Diversion to Coastal Marshes II: Application to Louisiana Coastal Protection and Restoration (LACPR). In preparation for *Ecological Engineering*.

McKay and Fischenich. Considering Uncertainty in Environmental Benefits Analysis: Coastal Wetland Restoration Case Study. *ERDC TN-EMRRP-EBA*. U.S. Army Engineer Research and Development Center, Vicksburg, Mississippi. http://cw-environment.usace.army.mil/test/eba/index.cfm